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AMSTR-NL-TN-010 Issue 4

Revised requirements for the pumps of the AMS Tracker Thermal Control System (TTCS)

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Document change log

Change Ref.	Section(s)	Issue 1.0
01	All	Initial issue, November 2001
Change Ref.	*Section(s)*	*Issue 1.1*
01	All	December 2002 Requirements with * are updated Decreased volume flow and pressure drop Increased Maximum Design Pressure MDP
Change Ref.	*Section(s)*	*Issue 2.0*
02	All	As input for final PDT proposal “TECHNICAL PROPOSAL TP-5059-2 AMS TRACKER THERMAL CONTROL SYSTEM PUMP PDT MODEL NO. 5059-2 Revision B 3 September 2004. Requirements with ** are updated
Change Ref.	*Section(s)*	*Issue 3.0*
03		Changes implemented according to MoM of the Kick-of Meeting 11-01-2005 Change in EM delivery date, Inclusion of environmental requirements. Correction of typos The changes (w.r.t issue 02) have been sidelined.
Change Ref.	*Section(s)*	*Issue 4.0*
04		Update of the electronics requirements in accordance with the TTCE design information Update of the TTCS loop lay-outs, mechanical lay-out and electronics overview

Summary

This document contains the fourth update of revised requirements for the pumps of the AMS Tracker Thermal Control System (TTCS). It also gives guidelines for the planning and programmatic aspects of the TTCS with respect to the timely delivery of the pumps.

Contents

1 Introduction of Alpha Magnetic Spectrometer (AMS)

The Alpha Magnetic Spectrometer (AMS) is a space born detector for cosmic rays built by an international collaboration. AMS will operate aboard International Space Station (ISS) for at least 3 years, collecting several billions of high-energy protons and nuclei. Its main goal is the search for cosmic antimatter, which is for anti-helium nuclei primarily. A first version of the detector, known as AMS-01, flew aboard the shuttle Discovery during the STS-91 mission (2-12 June 1998), collecting about hundred millions of cosmic rays. The precursor flight results confirmed the main ideas of the project and gave useful suggestions for further development. For the ISS mission, the detector will be slightly different in concept, but much better in resolution. In fact, AMS-02 will be an "improved" version of AMS-01, with a lower mass but with a more powerful cryogenic magnet and a few new sub-detectors.

2 AMS Tracker thermal control

NLR is developing a mechanically pumped two-phase carbon dioxide loop for the thermal control of the AMS Silicon Tracker, one of the most important AMS detectors. The Tracker, located inside the vacuum case, is surrounded by the cryogenic magnet, which is not allowed to receive any heat from inside. Moreover the Tracker has rather severe requirements regarding spatial and temporal temperature gradients. This and the existing complicated three-dimensional configuration, requires that the power dissipated in the Tracker (around 144 W) must be removed by means of an active mechanically pumped two-phase loop.

This two-phase loop named Tracker Thermal Control System (TTCS) incorporates long evaporators, picking up the heat from the multiple heat input stations evenly distributed over the 8 silicon planes. The heat is transported to a condenser connected to a heat pipe radiator. The liquid is transported back to the evaporator by means of a mechanical pump. Figure 1 and 2 in Appendix 1 show the concept of the TTCS.

3 Planning and approach

The total number of pumps is defined to be:

Phase 1: One (1) Engineering Model (EM)
One (1) Qualification Model (QM) → Flight Spare (FS)

Phase 2: Four (4) flight models (FM) including 2 controllers and 2 harness assemblies.

The EM pumps required for the breadboard model are to be used for verification of fluid properties (i.e. flow speeds required, pressure drop calculations etc.). and for implementation in the Engineering Model of the TTCS. The pump should therefore be flight-representative. The controllers should also be flight like but with industrial components instead of space qualified components. This approach is in line with the overall TTCS Model and verification approach.

3.1 Planning

The current, very tight planning for the AMS Tracker Thermal Control System is

Critical Design Review for the TTCS (CDR)	19/09/2004
Detailed Design Review (DDR)	29/04/2005
EM TTCS Test Readiness Review (EM-TRR)	28/09/2005
QM TTCS Test Readiness Review (QM-TRR)	08/03/2006
FM TTCS Delivery to CERN (FMD)	03/05/2006
FM TTCS Integration (FMI)	01/06/2006

From the above it is concluded that the delivery of a pump (e.g. the Engineering Model) should be as soon as possible but at the very latest in **August 2005**. The delivery of the Qualification Model should be as soon as possible but at the very latest at **January 2006**. The delivery of the Flight Units should be as soon as possible but at the very latest in **March 2006**, leaving NLR only very little time for acceptance testing and integration. It is stressed that in order to obey the current overall AMS schedule the two ultimate delivery dates cannot be shifted.

No travel from USA to Europe is foreseen and needs not to be included into your proposal.

3.2 Summary of deliverables and need dates

3.2.1 Hardware deliverables

Table 3-1 Deliverable pumps and need dates

quantity	pump model	need date
1	EM	August 2005
1	QM	January 2006 (TBC PDT)
4	FM	March 2006

3.2.2 Deliverable documentation

Table 3-2 Table of Data drop milestones

Data drop milestones	Responsible	Delivery date
PDR Draft data package	Contractor	21 February 2005
PDR final data package	Contractor	8 March 2005
CDR data drop package	Contractor	Mid August 2005
QM data package	Contractor	with QM
FM data package	Contractor	with FMs

Table 3-3 Table of deliverable documentation.

Documentation	Draft PDR	PDR	CDR	EM delivery	QM delivery	FM delivery
TN Safety Analysis Pump design (including vibration [1])	X draft	X	X		X	X
TN Pump Design Including: Pressure/flow characteristics Power consumption Mechanical (dimensions, envelope weight) characteristics Interface control drawings Electrical drawings and I/F specs. Matrix of compliance (by design, or similarity) with requirements specification Components list Mechanical parts list Materials list	X draft	X	X		X	X
Pump Design drawings	X draft	X	X		X	X
Pump Verification Plan	X draft	X	X		X	
Pump Test procedures	X draft	X	X		X	
Manufacturing documentation Component list Mechanical parts list Material list As built configuration data					X	X
QM Pump Qualification Test Report including matrix of compliance with requirements specification					X	
Acceptance test report				X	X	X
Management Documentation						
Progress reports (limited)	bi-monthly					
Schedule reporting (limited)	bi-monthly					

[1]) PDT to establish safety (analysis) requirements by mutual agreement with NASA.

4 Updated pump specifications for the AMS-Tracker Thermal Control System pumps

4.1 Introduction

The following requirement list contains the technical requirements for the TTCS pump and control electronics design. New developments in the design of the TTCS and discussions held with PDT engineers in February 2002 have led to an update of the requirements released in December 2002. In addition to those changes also the overall requirements changed and therefore also the requirements for the TTCS-pump. All these changes are implemented in this document.
The newly derived requirements are accurate for the development of the engineering unit. Only small changes are expected for the design of the qualification and flight units as the design is almost frozen. The largest changes with respect to the requirements from November 2001 are the decreased volume flow and pressure drop, the increased Maximum Design Pressure (MDP) and a change in diameter tubing. The separated location of the pump controllers is re-discussed and does not mean no electronics at the pump are allowed. “Dirty” signals between the pump location and the pump controller board should be avoided. However the main controller card is allocated as shown in Figure 6.

Requirement labels marked with “*” are changed compared to the release of November 2001.
Requirement labels marked with “**” are changed compared to the release of December 2002.
In issue 3 of this specification some additions and changes as discussed with PDT at the Contract Kick-off Meeting, see MoM dated 11 January -2005 have been incorporated. The changes are:

- Change in EM delivery date,
- Inclusion of environmental requirements.
- correction of typos

The changes (w.r.t issue 02) have been sidelined.

4.2 Pump requirements:

Req. Id	**Description**
UR-01	The pump shall be compatible with the working fluid liquid Carbon Dioxide (CO_2).
Remark	*The pump is in the liquid line, which can be close to the evaporation temperature and pressure. To prevent cavitation due to pump motor heat dissipation, cooling of the unit by the pumped liquid must be done after the compression.*
Remark	*It is a task of the manufacturer to specify the required delta p to avoid cavitation.*

Req. Id	**Description**
UR-02*	The maximum design pressure (MDP) shall be 160 bar.
Remark	*The MDP depends on the maximum occurring temperature during orbit and storage. (See UR-06) This temperature is rather unclear and depends on the design and safety approach of the TTCS component box. As long as the maximum occurring temperature of a non-operating TTCS is unknown a conservative value of 160 bar @ 80ºC is taken. Future developments may lead to a more relaxed MDP value. The relation between the MDP and this temperature is as follows:* • *125 bar @ 60ºC* • *140bar @ 70ºC* • *160 bar @ 80ºC (confirmed)* • *175 bar @ 90ºC*
UR-03*	The proof system pressure shall be 1.5 times the maximum design pressure (MDP) (see UR-02).
Remark	*No mechanical yield may occur during testing of flight hardware.* *The pumps shall be able to withstand the proof pressure without loss of function or performance degradation.*
UR-04*	The burst system pressure shall be at least 2.5 times maximum design pressure (MDP) (see UR-02).
UR-05	The operating temperature range shall be between –50 degrees Celsius and +25 degrees Celsius.
UR-06*	The storage and non-operating temperature range shall be between –60 degrees Celsius and + 80 degrees Celsius.
Remark	*See remark UR-02*
UR-07*	Relabelled, see UR-105
Remark	*Electrical requirements have been moved to a dedicated requirement section with labels in the 100 series*
UR-08*	Relabelled, see UR-201
Remark	*General requirements have been moved to a dedicated requirement section with labels in the 200 series*

Req. Id	**Description**
UR-09*	Relabelled, see UR-202
UR-10*	Relabelled, see UR-203
UR-11*	Relabelled, see UR-106
UR-12	The power consumption of the pump shall be as low as possible; the aim is less than 10 Watts.
Remark	*Please provide a power consumption characteristic figure as a function of pump speed and flow. The power consumption characteristics shall be split by pump-rejected heat and controller rejected heat.*
UR-13*	The pump-wetted volume shall consist of an all welded construction.
Remark	*Deleted*
UR-14**	The pump shall not contaminate the system working fluid Metallic particles are not allowed The maximum number of non-metallic particles in a 100 ml sample shall be as follows and is equivalent to MIL-STD-1246 C class 100: • > 100µm none • 100 µm 5 max • 50 µm 50 max • 25 µm 200 max • 10 µm 1200 max • 5 µm no limit
UR-15*	The two-pump system weight shall be as low as possible, but anyhow lower than 1 kg
UR-16*	The pump envelope shall be according to PDT drawing TP-5059-1, Revision A, Figure 4.0.
UR-17* **	The minimum flow rate shall be as low as possible and approximately 1 ml/s and 150 mbar
Remark	*The preliminary TTCS pressure/flow characteristics are displayed in figure 5 of Appendix I. Please provide the minimum possible pump flow or speed.*

Req. Id	**Description**
UR-18**	The maximal flow rate shall be 4 ml/s at 850 mbar dP (TBC by experiments in near future).
*Remark***	*The TTCS pressure/flow characteristics are displayed in figure 5 of Appendix I.*
*Remark***	*Please check first if a single stage centrifugal pump is currently within reach. Please provide a characteristic for a single stage and a dual stage pump.* *Please provide the pump performance characteristics for pump speed settings from the minimum to the maximum speed*
UR-19*	The pump shall be able to operate within a magnetic field between 140 and 1000 Gauss, depending on its final location inside the TTCS component box.
Remark	*Note that the pump is located close to the strong magnetic field generated by the cryogenic cooled magnet. A complete plot of the magnetic field is shown in figure 4 of Appendix I. Please specify the maximum allowed magnetic field for the pump, and the desired orientation of the pump with respect to the field lines. The pump can be tested in the AMS magnetic field test facility at MIT in Boston.*
UR-20*	It shall be possible to switch the pump on/off at least 1 time per day.
Remark	*Deleted*
UR-21*	The mechanical interfaces shall be according to PDT drawing TP-5059-1, Revision A, Figure 4.0. (**remark the tubing diameters are changed see UR-22)
Remark	*Deleted*
UR-22* **	The connecting tubes shall be 6 mm (outer diameter) and 4 mm inner diameter seamless tube. Material should be 316L CRES for orbital welding to the rest of the TTCS tubes. The tubes shall protrude at least 150 mm. The orientation of the tubes with respect to the envelope (UR-16) and mounting interface (UR 21) is TBD
UR-23*	Relabelled, see UR-204
UR-24*	Relabelled, see UR-205
UR-25*	The pump shall have integrated check valves to prevent back flow when not operating.

Req. Id	**Description**
UR- 26*	None of the pumps shall be operating during lift-off and landing.
UR-27*	All flight hardware pressurized components shall be designed according to Military Standard document MIL-STD-1522A (Standard General Requirements For Safe Design And Operation Of Pressurized Missile And Space Systems)
Remark	*Requirements UR-03 and UR-04 are derived from this document*
Remark	*A summary of pressure related design rules is given in Appendix II, section B.*
UR-28*	All flight hardware welds shall be designed, made and tested according to NASA document: PRC-0010, Rev A (Process Specification for Automatic and Machine Arc Welding of Steel and Nickel Alloy Flight Hardware.

4.3 Electrical requirements:

Req. Id	**Description**
	Performance
UR-101*	The pump rotational speed shall be continuously variable. Speed control signal (ref. UR-102) scaling: Linear, 0 V ≡ 0 RPM, +3 V ≡ TBD RPM. Note: At any control voltage below TBD V the motor speed will be set to 0 RPM.
	Control
UR-102* **	Pump speed control signal: 1 analogue speed command signal, 1 reference (return line). Range: 0.00 … +3.00 V_{DC}, source impedance < 1 Ω (12-bit D/A converter). In the pump controller, the signal is loaded by a symmetrical differential input in the pump control electronics, Z_{in} = 50 kΩ per leg. Signal bandwidth: 10 Hz. Reconstruction noise from the D/A converter may exist in the pump speed control signal.
	Mechanics
UR-103*	The controller mechanics shall be compatible with the standard AMS electronic boards as specified in Appendix III (if applicable).
Remark	*Each pump shall have its own power supply and control electronics. In this way it shall be possible to operate all pumps independently.* *One control electronics assembly shall not share components with other*

Req. Id	Description
	controllers. They shall be electronically completely separated.
	Monitoring
UR-104*	The pump speed shall be monitored: 1 digital tacho signal will be output, with 1 reference. The square-wave signal is driven by the pump control electronics as an open-collector output that can handle +5 V in the high state and 10 mA in the low state. The signal frequency is a measure for the rotational speed of the pump motor. Scaling: Linear, 0 ... 1.35 kHz, scaled as 6 or 9 pulses per revolution of the motor.
	Power supply
UR-105	The operating voltage for the pumps and the controllers will be 28Vdc, which will be supplied by TTPP. Connections: +28 V_{DC}, max. 540 mA, 1 return. The +28 V_{DC} output is switched ON/OFF under software control. Inrush current at power-on must be limited to max. 5 times the nominal current.
Remark	*Each controller shall have its own power supply connection.* In addition, the pump control electronics will deliver a DC supply to TTPP when the pump's 28 V supply is switched on: +5 V_{DC}, max. 100 mA, 1 return. This supply is generated in the pump control electronics and the +5 V return is connected to the +28 V return in the pump control electronics.
	Radiation tolerance and parts selection
UR-106*	The electronics shall withstand a TBD radiation level.
Remark:	*AMS has specified it's own radiation requirements. The requirements will be provided by the AMS electronic integration office.*
UR-TBD	Electronic parts must preferably be selected from the AMS Preferred Parts List or Master Parts List. If other parts must be used, this must be discussed in detail with the AMS team. A full bill of materials must be submitted to the AMS team for approval at the Critical Design Review.
	General
UR-107*	The power and communication cable between the pumps and the controllers shall be able to function over a distance of at least 5 m.
Remark:	*Please specify any constrains due to long cables.*
	Temperature range
UR-108*	The controllers' operational temperature range shall be between -20 ºC and 55 ºC

Req. Id	Description
Remark	*The controllers are in a different thermal environment as the pumps.*
UR-109*	The controllers' non-operational temperature range shall be from -40 ºC to +80 ºC
Remark	*The controllers are in a different thermal environment than the pumps.*
	Magnetic field tolerance
UR-110*	The controller shall be able to operate within a magnetic field of 800 Gauss.
Remark	*See remark UR-19, A detailed magnetic field plot for the controller location (similar to figure 4) will be provide in the near future*
	Reliability
UR-111*	An estimation of the MTBF of the controller electronics will be supplied. For example via the parts count method of MIL-SPEC-217F. The MTBF shall not be lower than 45,000 hours.
	Procurement policy
UR-112*	For all EEE parts, spare parts will be procured (not assembled) exclusively available for use for the AMS-02 mission. Guideline will be an amount of 15% with a minimum of 2.

4.4 General requirements:

Req Id	Description
UR-201	The nominal lifetime of the pump and controller shall be 3 years.
Remark	*The lifetime of the pump is to be proven by a FMECA, herewith supporting the overall cooling system redundancy approach.*
UR-202	The pump and controller shall be maintenance free (as the location of the hardware is inside the AMS, which is attached to the truss of the ISS).
UR-203	The pump and controller shall be able to operate in high vacuum (1*10-6 mbar), see also UR-204 and UR-205.
UR-204	The pump and controller shall be compliant with requirements for Space Shuttle Launch.
UR 205	The pump and controller shall be compliant with requirements for ISS (external

Req Id	Description
	site).
UR-206*	The usage of the following materials on the controller and the pump, including its connectors, is prohibited: Beryllium, beryllium alloys and oxides, cadmium and zinc. Chlorinated cleaning agents shall not be used during manufacturing, testing, storage or other handling; Polyvinyl chloride products shall not be used.
UR-207*	Mechanical structures should be designed according to NASA- document JSC-2045RevA (Simplified Design Options for STS-Payloads) to withstand launch and landing loads and frequencies.
Remark	*A summary of the design load factors is given in Appendix II, section A & C*

4.5 Electromagnetic compatibility requirements

Req Id	Description
UR-208	**Compliance with ISS EMC requirements.** The pumps shall be compliant with the EMC requirements for AMS-02. The applicable AMS-02 EMC requirements are based on the ISS (external site) EMC requirements specified in SSP 30237, Rev. F. The requirements (EMC levels and tests) from SSP 30237, Rev. F applicable for AMS-02 and hence for the pumps, are listed in this present specification, see Appendix IV, Table 4-2 Table of EMC requirements applicable to AMS-02 In the Appendix IV Table 4-2 the applicable requirements are listed for: - conducted and radiated emission and - conducted and radiated susceptibility, which are to be verified by test, according to SSP 30237Rev.F. The conducted and radiated susceptibility requirements shall be verified by test (T) on the QM pump or by similarity (S), if similar or better qualification results for the offered pumps are available.

4.6 Structural verification requirements

Req Id	Description
UR-209	**Proof pressure requirements test** The QM pump shall be subjected to a proof pressure test. The proof pressure

Req Id	Description
	shall be 1.5 times the maximum design pressure (MDP). The pump shall be able to withstand the test without function loss or performance degradation, which shall be checked after the proof pressure test.
UR-210	**Vibration requirements** The QM pump shall be subjected to a random vibration test, according to the Minimum Workmanship Levels (MWL), specified in Appendix II, section D of this document. The pump shall be able to withstand the test without function loss or performance degradation, which shall be checked after the vibration test...
UR-211	**External leak tightness requirements.** The external leak tightness of the pumps shall be lower than $1*10^{-8}$ mbar*l/s CO_2 at 160 bar.

4.7 Product Assurance and Quality Management requirements

Req Id	Description
UR-212	**Audit requirements** The customer is entitled to perform quality audits at the manufacturer's premises.
UR-213	**Materials traceability** Materials and parts traceability shall be provided from the incoming inspection at the contractor until the delivery to the customer.
UR-214	**Serial numbers** The pumps shall each have a unique serial number specified by the manufacturer. The serial number shall be visible at the outside surface of the pumps.
UR-215	**Non conformance reporting** Non-conformances related to the deliverable pumps shall be reported to the customer.

Appendix I : TTCS Loop schematics and mechanical lay-out

A: TTCS Loop lay-outs

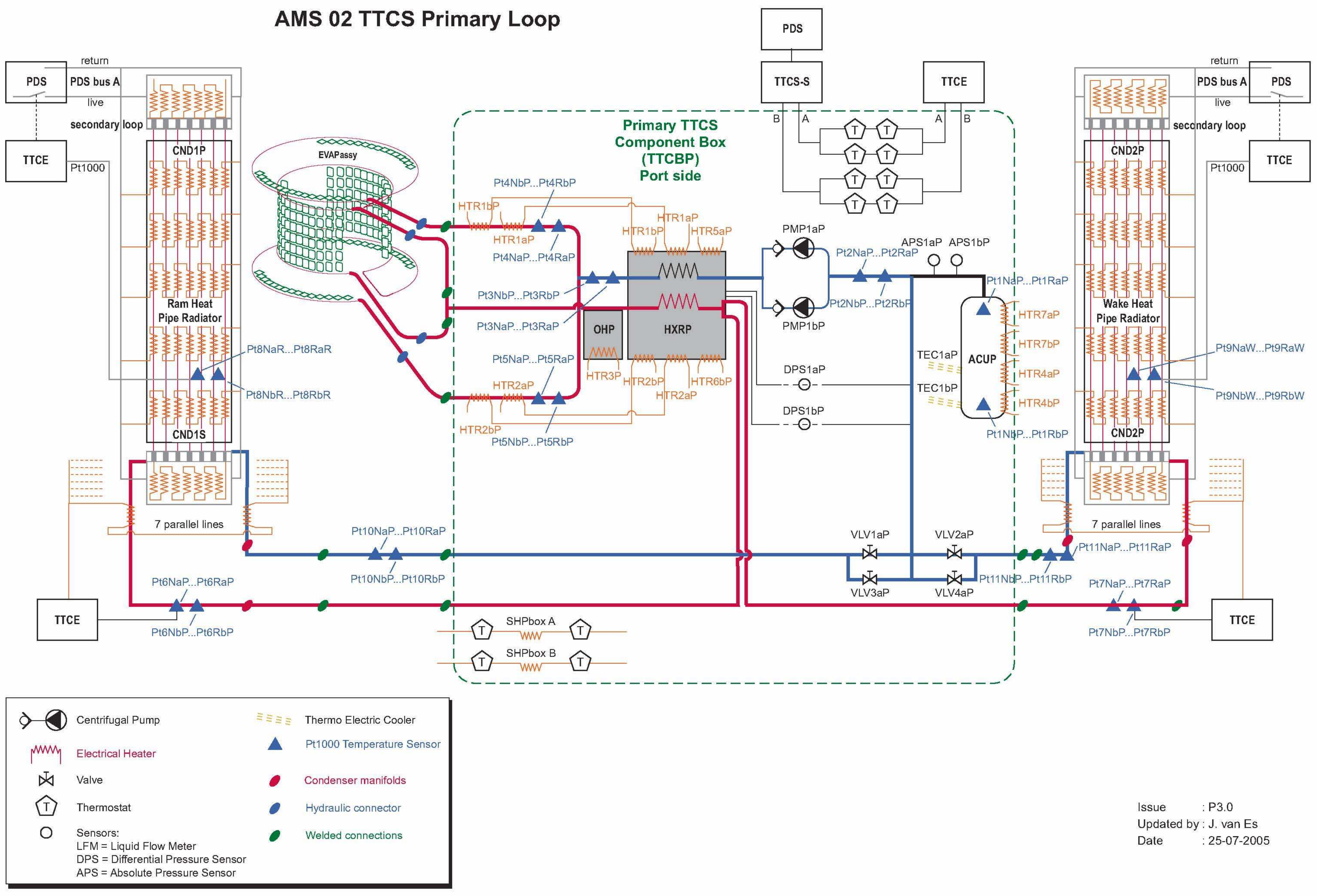


Figure 4-1: Tracker Thermal Control System Schematic Primary Loop

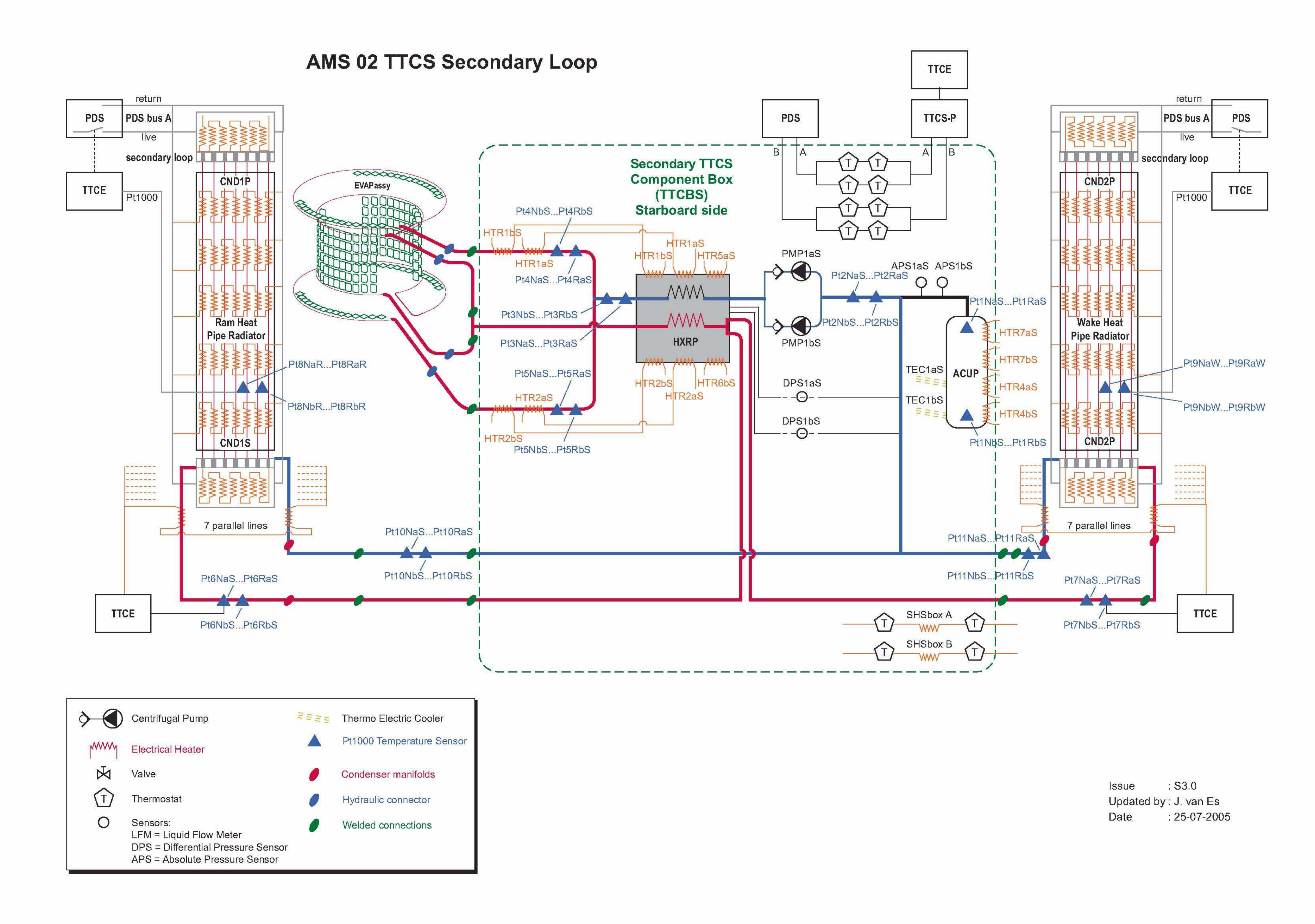


Figure 4-2: Tracker Thermal Control System Schematic Secondary Loop

B: Mechanical lay-out

In the below figures the main hardware locations of the TTCS-system are indicated.

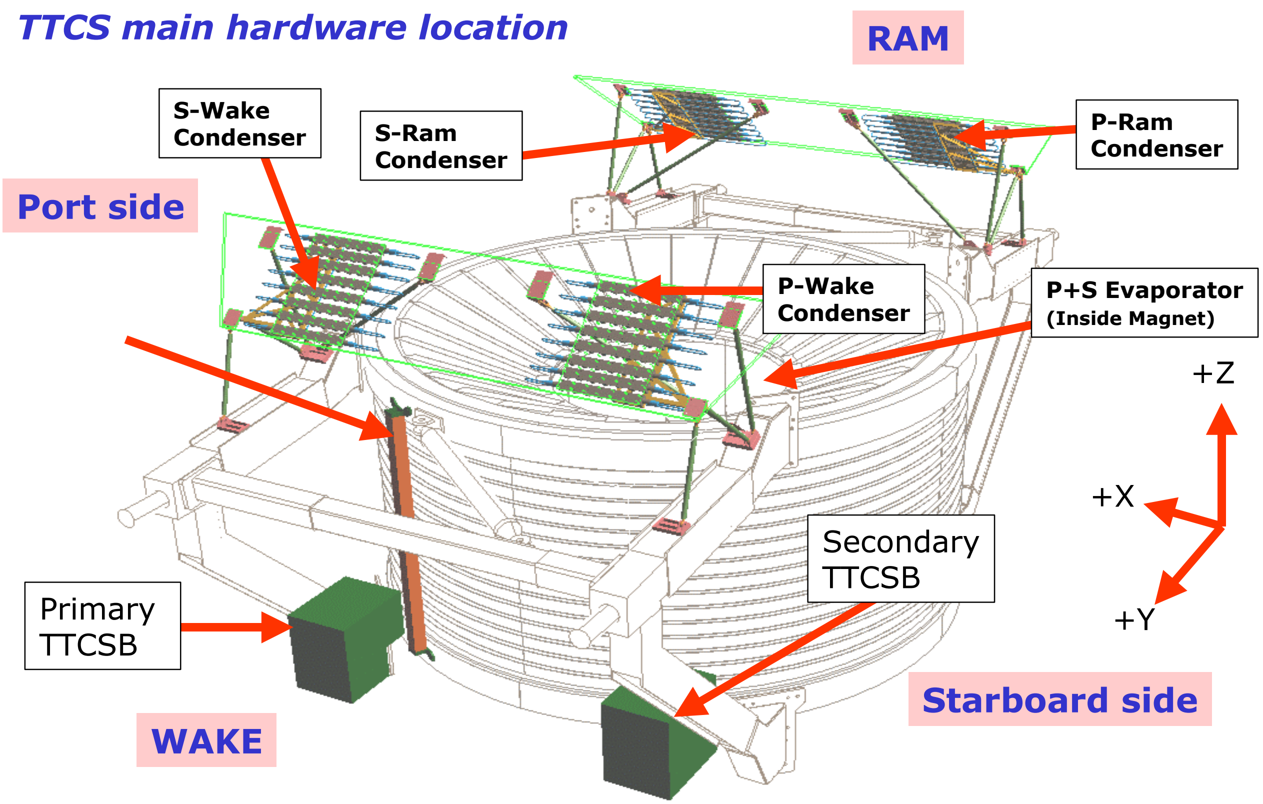


Figure 4-3: TTCS Hardware location

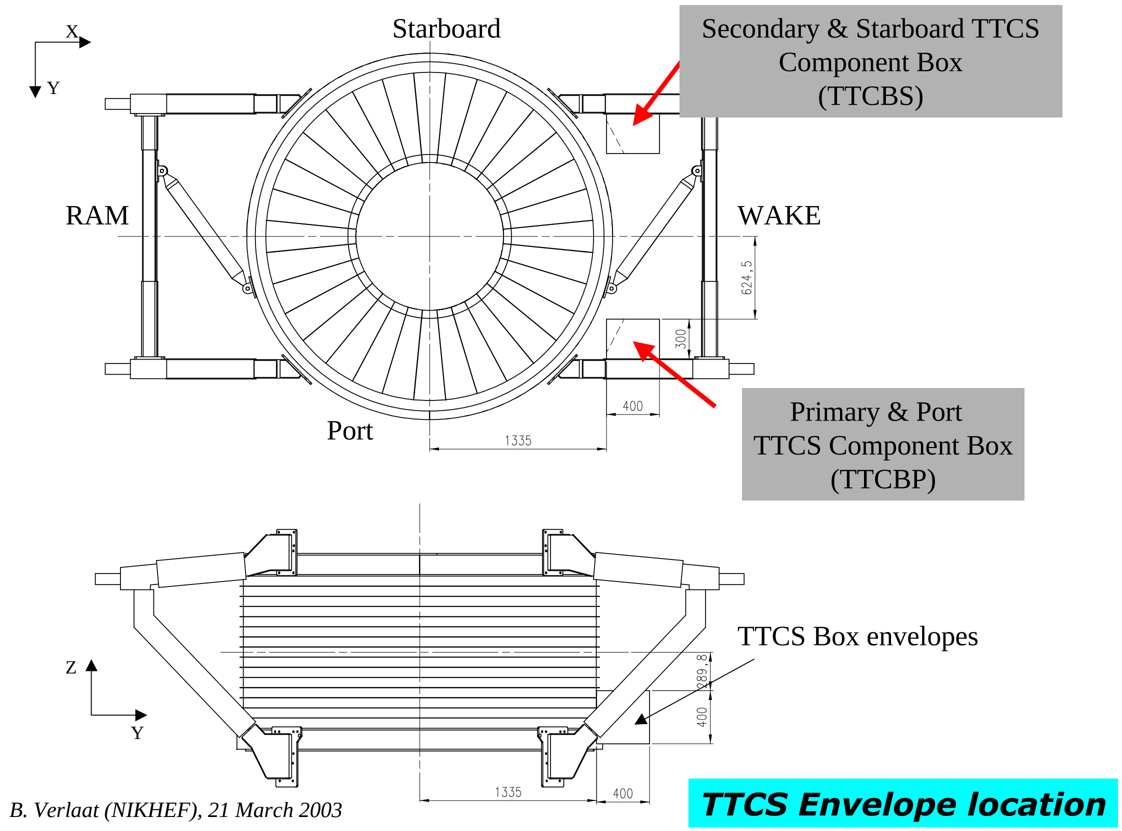
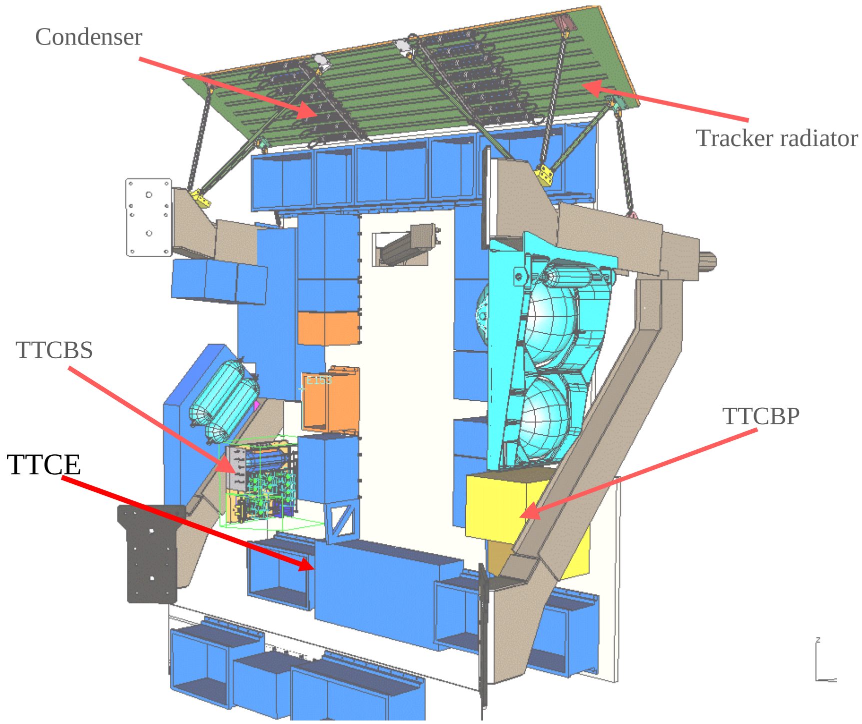


Figure 4-4: Location of the TTCS hardware (1/3) (Top view)



(Port side detail)
Figure 4-5: Location of the TTCS hardware (2/3)

TTCS Control
Electronics box
(TTCE)

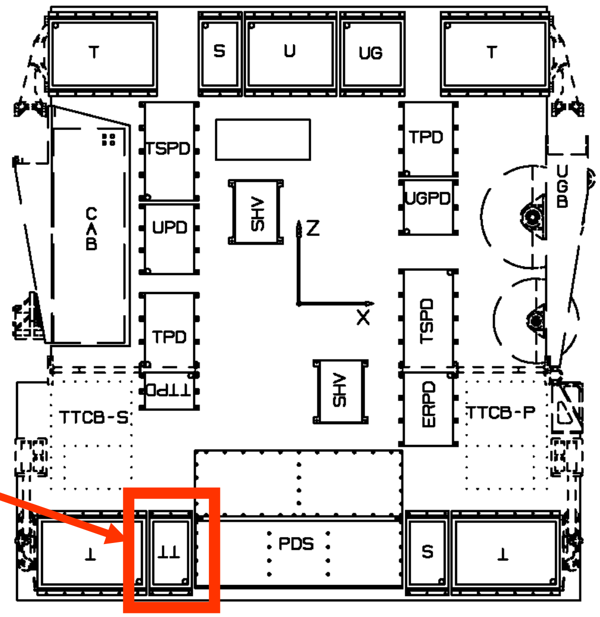


Figure 4-6: Location of the TTCS hardware; TTCE location at wake radiator (2/3)

C: Preliminary box lay-out

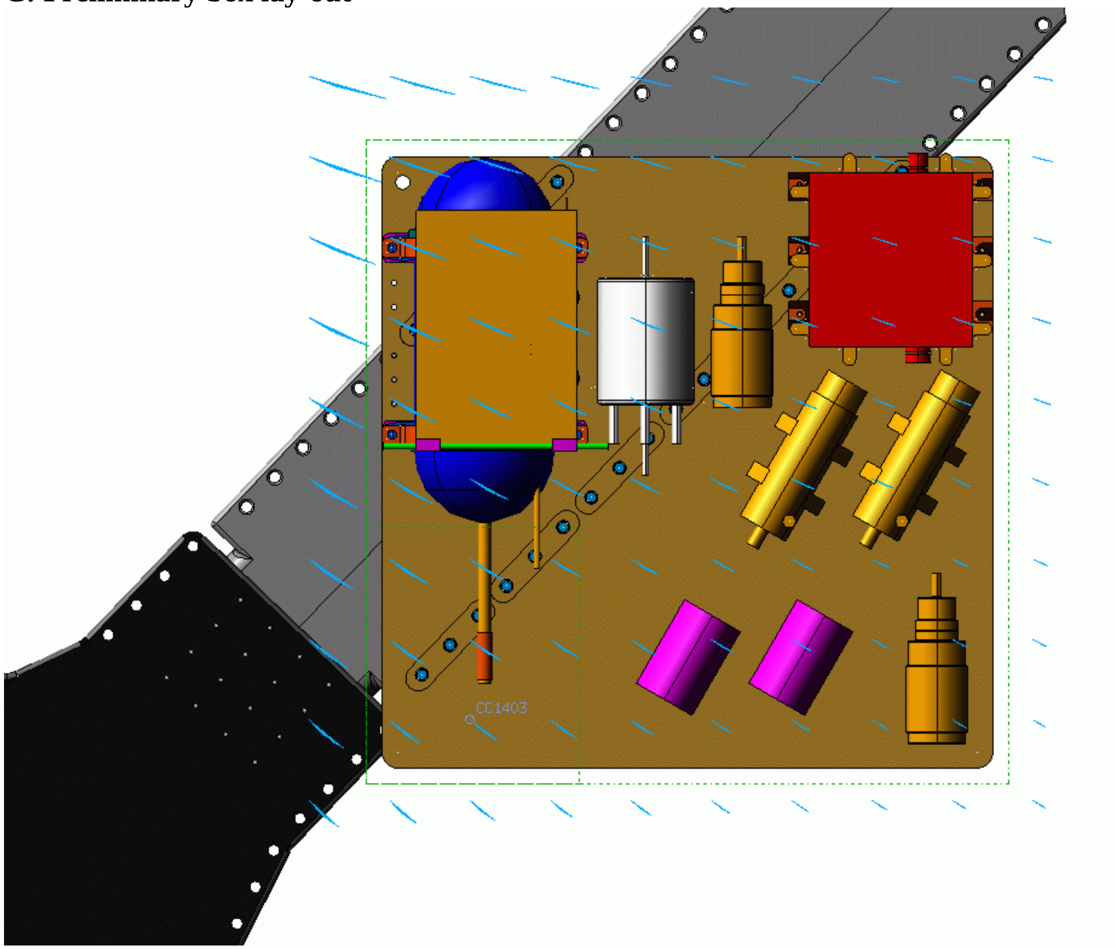


Figure 4-7: Preliminary lay-out of the primary box

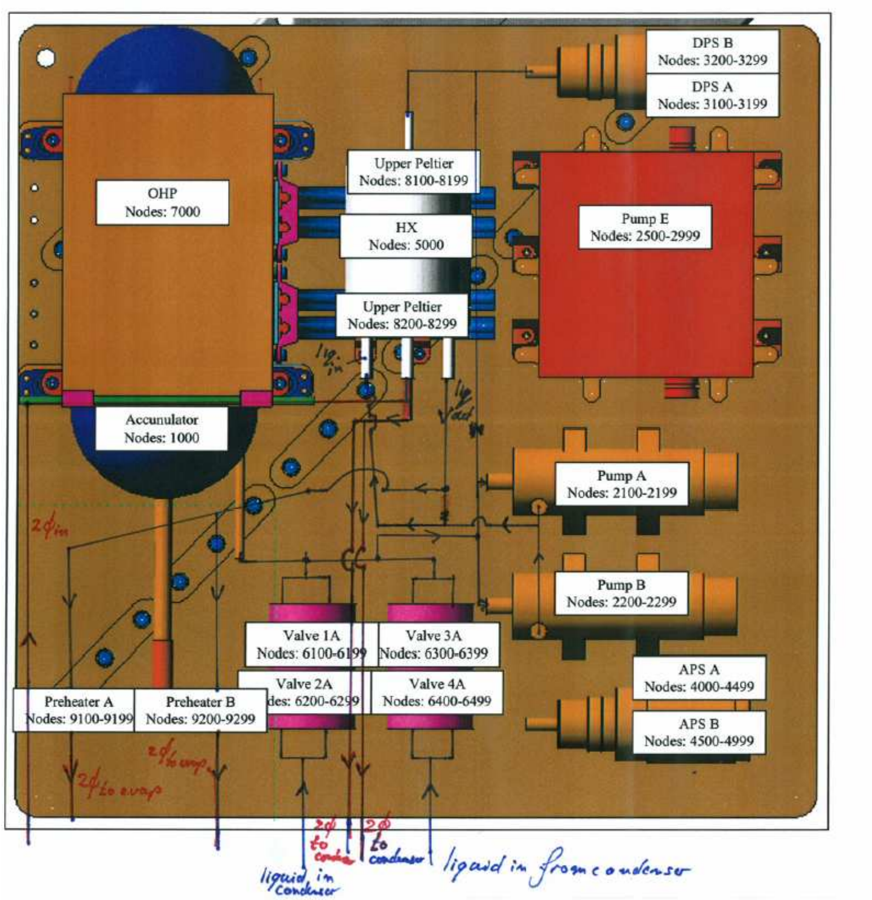


Figure 4-8: Primary TTCS-P box Preliminary Lay-out (components location is under design)

D: Magnetic field map

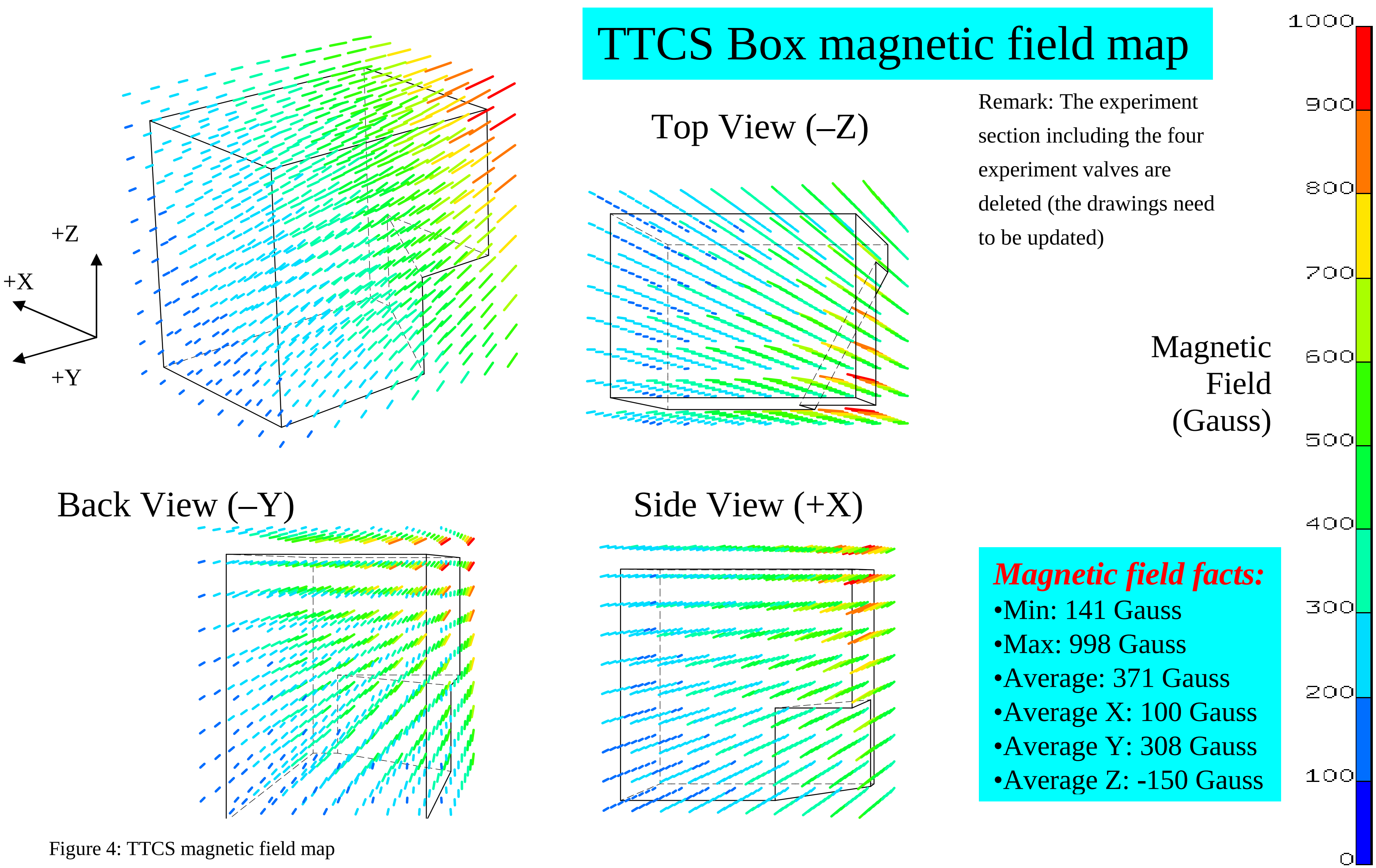
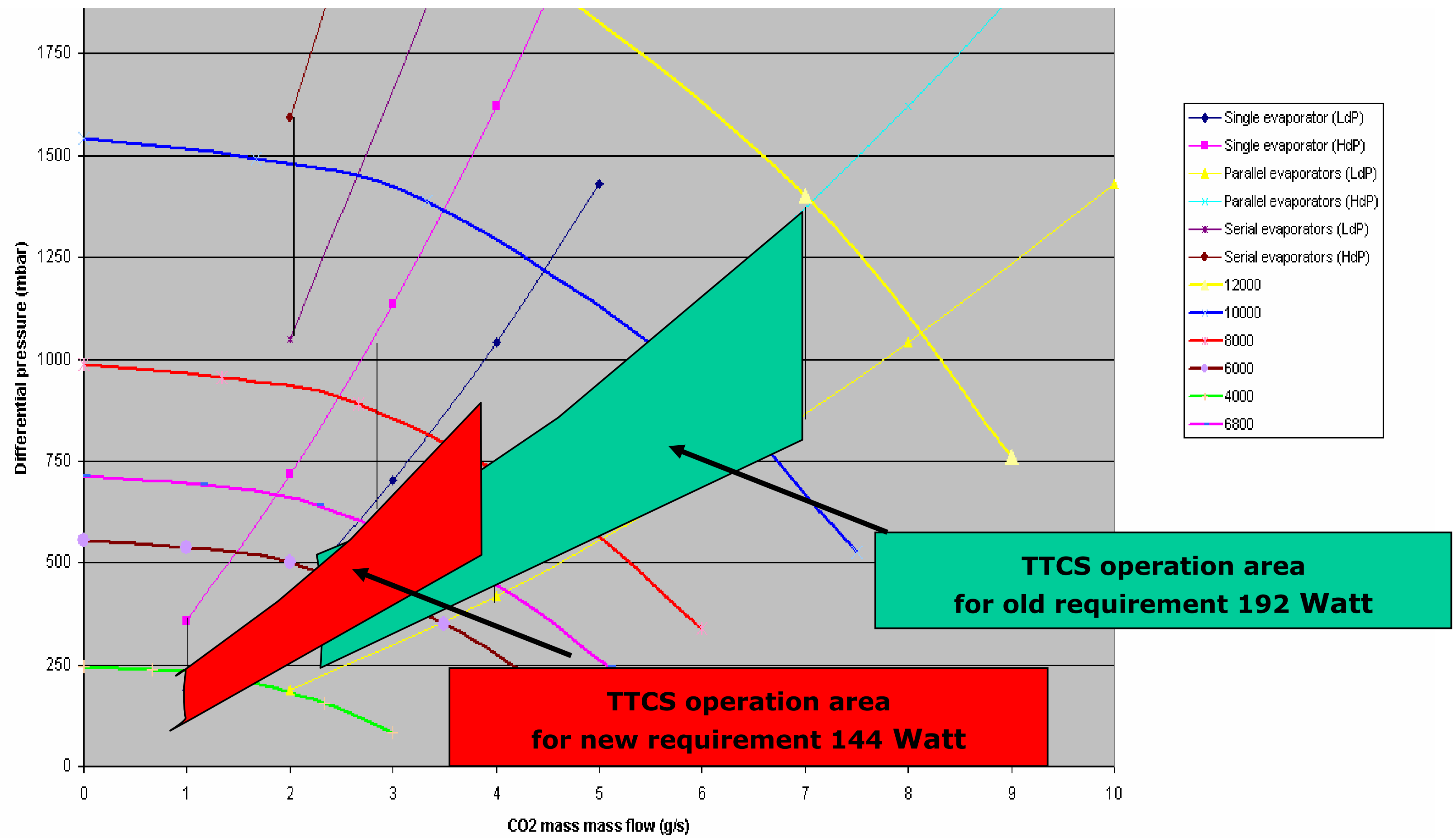


Figure 4: TTCS magnetic field map

TTCS pump operational areas.

(Shown pump performance lines are estimated performances derived from PDT Model 5059-1 proposal Rev A, 13 sep 02)



Appendix II TTCS Structural Verification Requirements Summary

A. Structural verification for flight components:

Ultimate load = Ultimate factor of safety x Limit load
Yield load = Yield factor of safety x Limit load

A1: The “Ultimate load” is the maximum load, which the structure must withstand without rupture.

A2: The “Yield load” is the load, which the structure must withstand without permanent deformation.

A3: The “Ultimate factor of safety” (FSu) and the “Yield factor of safety” (FSy) are the safety factors needed to calculate the “Ultimate loads” and “Yield loads.” These factors are:

Table 1:

No static testing required:
FSu = 2.0
FSy = 1.25

If the structure is static tested factors of safety can be reduced to:
FSu =1.40
FSy = 1.10

A4: The “Limit load” is the maximum load expected on the structure during its design service life. A simple way of defining the limit load is according the method from document: JSC 20545, Rev. A.

Limit load = Load factor x Weight

The load factor is according to table 2.

Table 2:

Component weight (lbs.)	Load factor (g)

<20	40
20-50	31
50-100	22
100-200	17
200-500	13

These load factors should be applied in any axis with a load factor equal to 25% applied to the 2 orthogonal axes simultaneously.

A5: All the hardware needs to have a first resonance frequency higher than 50 Hz, than no dynamic tests are required. If the resonance frequency is lower than 50 Hz but higher than 35 Hz, a sine sweep, smart hammer or modal testing is required.

B: Structural verification for pressurized systems:

Ultimate pressure = Ultimate pressure factor x MDP

B1: Where “MDP” stands for “Maximum Design Pressure”. MDP for a pressurized system shall be the highest pressure defined by the maximum relief pressure, maximum regulator pressure or maximum temperature.

B2: The “Ultimate pressure factor” is a multiplying factor applied to the MDP to obtain ultimate pressure. Pressurized components are to be designed to the following factors of safety.

Table3:

Lines and fittings:	Burst	Proof
Diameter <1.5”	*4.0*	*1.5*
Diameter =>1.5”	*2.5*	*1.5*
Other components	*2.5*	*1.5*

B3: In case of a pressurized system, the loads caused by the ultimate pressure needs to be added to the ultimate load caused by vehicle acceleration.

B4: To test the system for evidence of satisfactory workmanship, a proof pressure needs to be applied.

Proof pressure = Proof factor x MDP

The proof factor is determined in table 3.
Pressurized components shall sustain the proof pressure without detrimental deformation.

C: Fracture analysis:

C1: Pressurized components or sealed containers that have a non hazardous Leak-Before- Burst (LBB) mode of failure may be classified as low risk fracture parts.
C2: To classify mechanical fasteners as fail-safe it must be shown by analysis or test that the remaining structure after a single failure of the highest loaded fastener can withstand the loads with a factor of safety of 1.0
C3: Components in a sealed box do not need structural verification when it can be proved that the released parts are completely contained and will not cause a catastrophic hazard.
C4: All fasteners larger than M3 (US #8 and above) are subject to NASA structural testing. It is recommended to use NASA provided MS- or NAS- fasteners.

D: Random vibration requirements: Minimum Workmanship Vibration Test Levels

axis	frequency	level
all axes Test duration 60 seconds per axis	< 20 Hz	0
	20 Hz	0.01 g^2/Hz
	20-80 Hz	increasing 3 dB/Octave
	80-500 Hz	0.04 g^2/Hz
	500-2000 Hz	decreasing 3 dB/Octave
	2000 Hz	0.01 g^2/Hz
	> 2000 Hz	0

Table 4-1 Table of Minimum Workmanship random vibration test levels

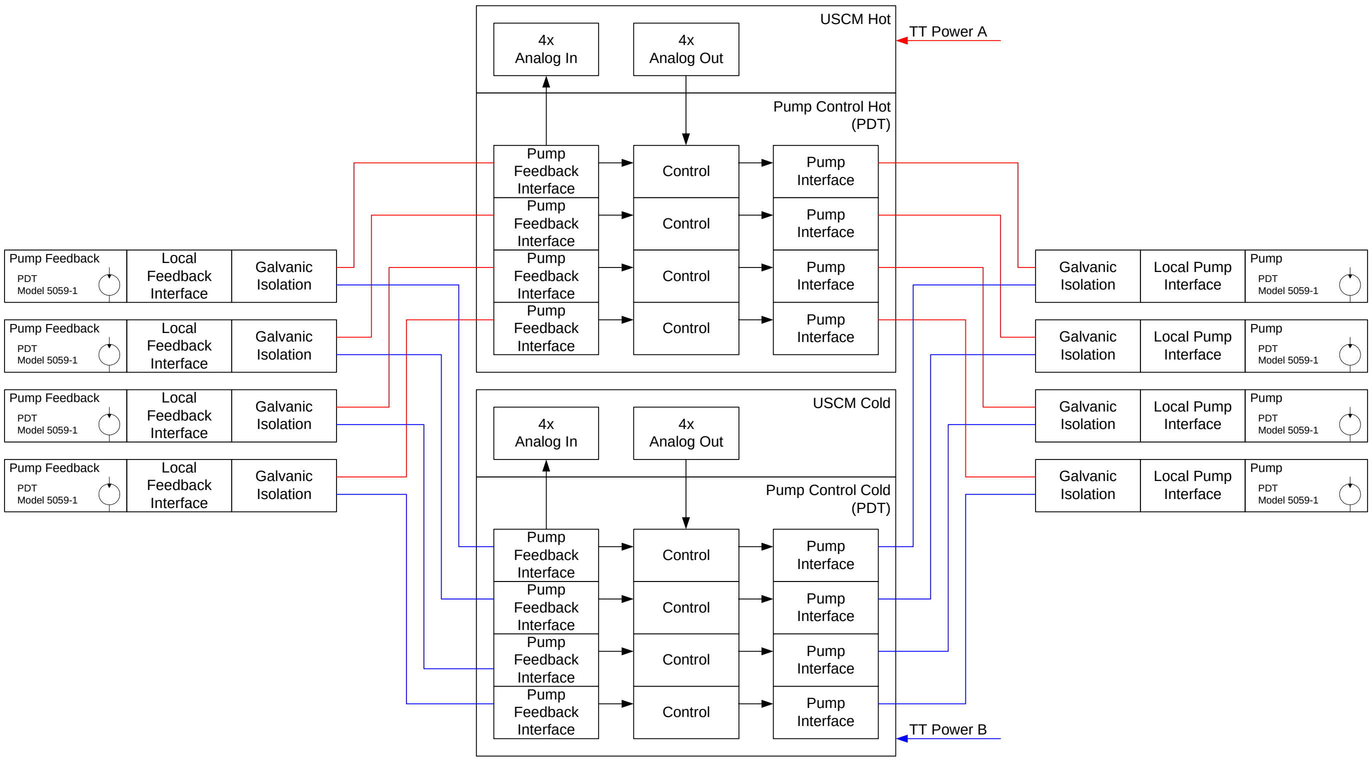
Appendix III Preferred pump control schematics and TTCS operation

On the following page the preferred pump control schematic is shown. The USCM is however replaced by own developed interface electronics.
The pump electronics will be integrated in the overall electronics of the Tracker Thermal Control System (TTCS). For a successful, reliable, power- and mass-effective design co-ordination and close co-operation between NLR and PDT on the electronics is required.

The most important electronics issues to be discussed are:

- Total 4 controls on each pump board (see figure)
- Galvanic isolation of USCM hot & cold pump connections
- Amount of electronics located on pump

May be PDT can provide on forehand a preliminary ICD for power budget and wiring design.



TTCS remarks/notes:
1) TTPD completely hot/cold redundant
2) TTCS power ground isolated from chassis (TBC)
3) Pump interface lines galvanic isolated for hot/cold (optocouplers)
4) Local electronics on pump to have an solid interface

	NATIONAL AEROSPACE LABORATORY NLR ELECTRONICS DEPARTMENT						
	AMS Tracker Thermal Control Electronics Pump Overview						
CAM Rens	SIZE A3	FSCM NO Pump		DWG NO AMS_030723 Electronics Block diagram 0.0.3.vsd			REV A
	SCALE	1 : 1	DATE 6-8-2003		SHEET	5 OF 6	

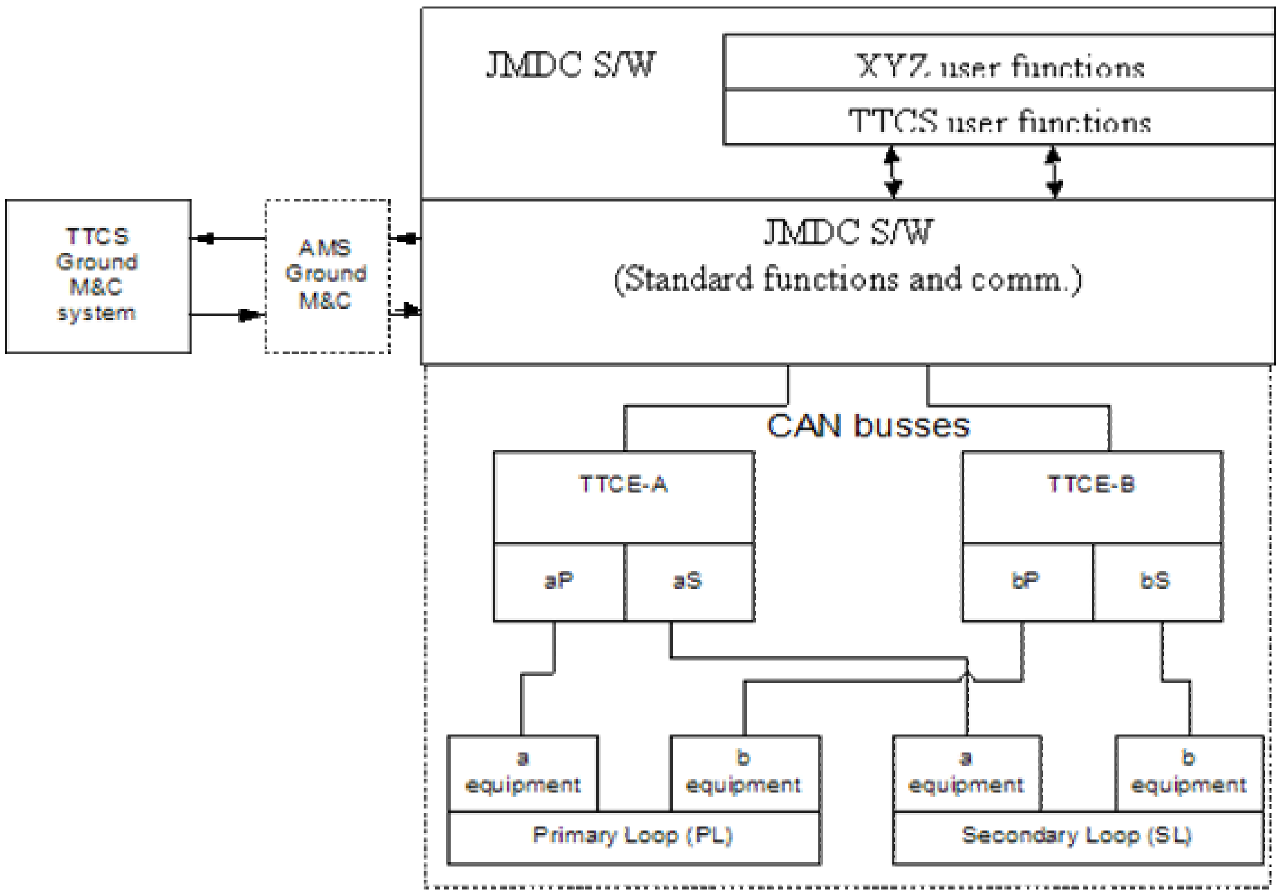
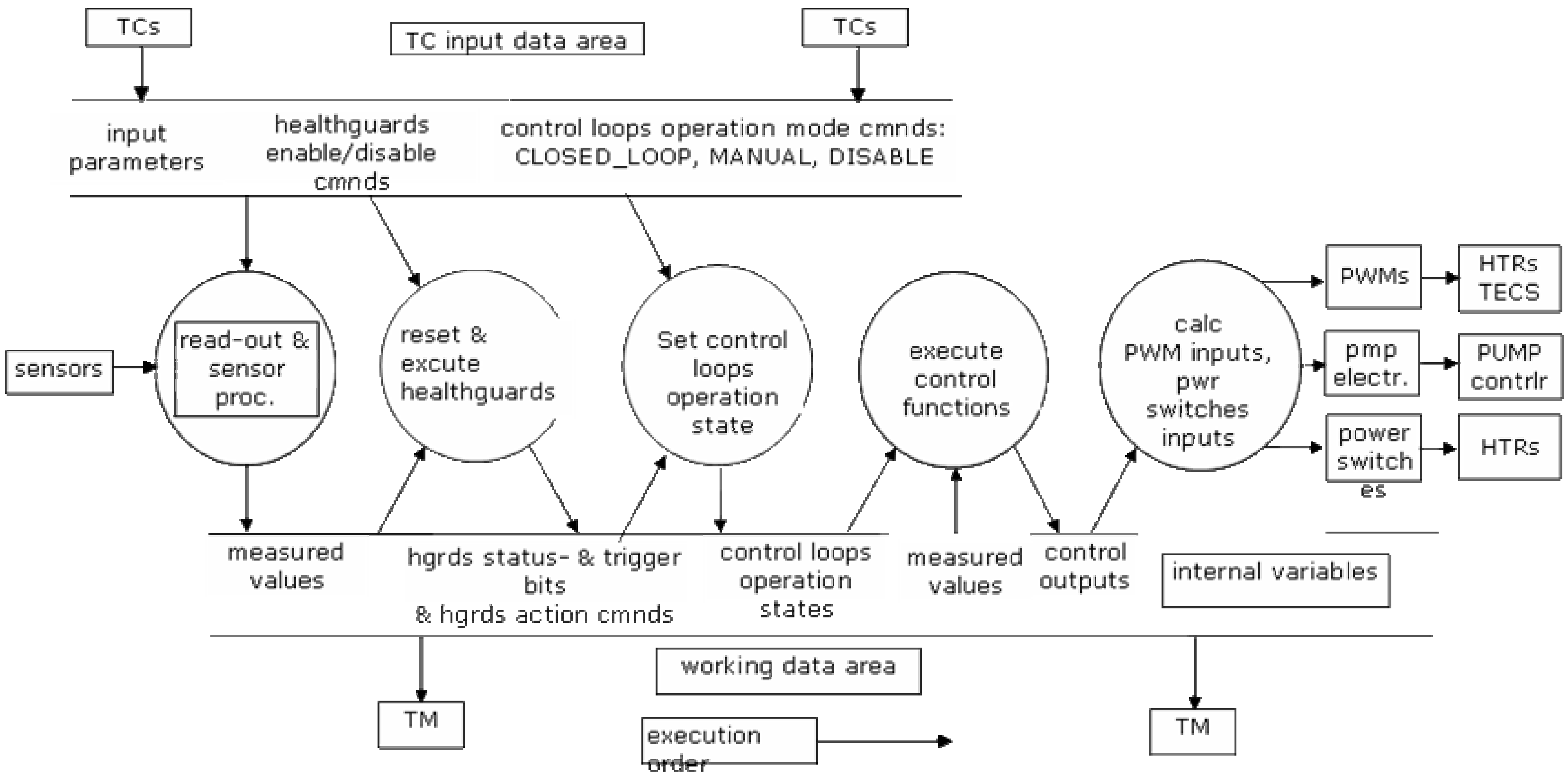


Figure 4-9 Overview of TTCS Space Segment and TTCS Ground M&C System.



Dataflow diagram of proposed healthguards and control software

Figure 4-10: TTCS Dataflow diagram

Appendix IV EMC requirements applicable to AMS-02

EMC Requirements Applicable to
AMS-02

Type of Test/Requirement	Name of Test	Coverage	Applicability to AMS-
Conducted Emissions	SSP 30237, Rev F CE01	DC power, lo freq, 30 Hz to 15 kHz.	Required
Conducted Emissions	SSP 30237, Rev F CE03	DC power, 15 kHz to 50 MHz.	Required
Conducted Emissions	SSP 30237, Rev F CE07	DC power leads, spikes, time domain.	Required
Conducted Susceptibility	SSP 30237, Rev F SSP 30237 SSCN 3282 D.2 CS01	DC power leads, 30 Hz to 50 kHz.	Required
Conducted Susceptibility	SSP 30237, Rev F SSP 30237 SSCN 3282 D.2 CS02	DC power leads, 50 kHz to 50 MHz.	Required
Conducted Susceptibility	SSP 30237, Rev F SSP 30237 SSCN 3282 D.2 CS06	Spikes, power leads.	Required
Radiated Emissions	SSP 30237, Rev F RE02	Electric field, 14 kHz to 10 GHz (narrowband), 13.5 -15.5 GHz.	Required
Radiated Susceptibility	SSP 30237, Rev F RS02	Magnetic induction field	Desired by EP4/JSC
Radiated Susceptibility	SSP 30237 SSCN 3282 PIRN 57003-NA-0023 RS03PL	Electric field, 14 kHz to 20 GHz.	Desired by EP4/JSC

Table 4-2 Table of EMC requirements applicable to AMS-02

An excerpt from the applicable SSP 30237 SSCN 3282 PIRN 57003-NA-0023 RS03PL mentioned in the above table for radiated susceptibility, is given on the next page(s).

ISS PAYLOAD OFFICE IRN/PIRN/EXCEPTION

Doc. No., **SSP 57003, Initial Release**

Rev. & Title: **Attached Payload Interface Requirements Document**

PIRN NO: **57003-NA-0023**

(P)IRN TITLE: **Relaxation of EMI RS03 Requirement Per SSCN 3282**

SSCN/CR SSCN 3282

Agency Tracking No.: 57003-0026

SYSTEM/ELEMENT AFFECTED & STAGE EFFECTIVITY: **EME**

REASON FOR CHANGE: (INCLUDE APPLICABLE ICAP NUMBER):

Relaxation of RS03 requirements in accordance with SSCN 3282 .

PARAGRAPHS, FIGURES, TABLES AFFECTED (For PIRN use only)

Page **3-27**

Paragraph(s) **3.2.2.4.4**

From:

3.2.2.4.4 ELECTROMAGNETIC INTERFERENCE

Payload EPCE shall meet all Electromagnetic Interference (EMI) requirements of SSP 30237.

To:

3.2.2.4.4 ELECTROMAGNETIC INTERFERENCE

Attached Payloads shall meet all Electromagnetic Interference (EMI) requirements of SSP 30237.

Alternately, Attached Payloads may choose to accept a minimal increase of EMI risk with a somewhat less stringent Electric Field Radiated Susceptibility (RS03) requirement on equipment considered to be non-safety critical to the vehicle and crew. The tailored RS03 requirement, shown below, will hereafter be denoted RS03PL.

FREQUENCY	RS03PL LIMIT (V/m)
14 kHz - 400 MHz	5
400 MHz - 450 MHz	30
450 MHz - 1 GHz	5
1 GHz - 5 GHz	25
5 GHz – 6 GHz	60
6 GHz – 10 GHz	20
13.7 GHz – 15.2 GHz	25

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